

A TECHNIQUE FOR BREAKING ICE IN THE PATH
OF A SHIP

The invention relates to the use of a laser for cutting or shattering ice in the path of a ship thereby enabling the ship to move through the ice.

The invention consists essentially of a laser 11 on the bow of a ship 12. The beam 16 from laser 11 strikes a scan mirror 14. The reflected beam 17 scans the layer of ice 13 in front of ship 12. Beam 17 either cuts or shatters ice 13 thereby enabling the ship to move through the ice.

The apparatus used in this invention is shown in more detail in FIG. 2. The beam 16 from CO₂ laser 11 is directed into a beam splitter 18. The part of beam 16 that is reflected is again reflected by mirror 19 onto photodetector 20 which indicates the intensity of beam 16. The part of beam 16 that passes through beam splitter 18 is reflected by a parabolic mirror 21 onto a rotating scan wheel mirror 22 which is driven in a clockwise direction by a clock drive 23. Scan mirror 22 has five surfaces, hence each time the mirror rotates through 72 degrees, the laser beam will be reflected by a different surface. Consequently, each time the mirror rotates through 72 degrees, the reflected beam 17 will scan from a point in front of the ship to the left through 72 degrees. The scan mirror can have any number of reflecting surfaces other than two as shown in FIG. 1 or five as shown in FIG. 2.

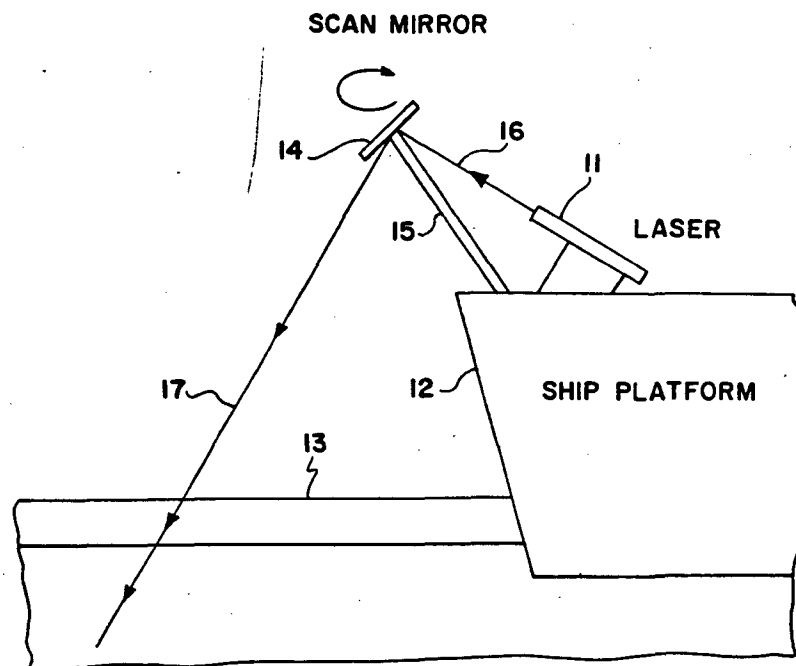
CO₂ laser 11 usually operates in a continuous mode. Q-switching of laser 11 is required for operating it in a high power, rapid-pulsed-mode. In this mode, the inversion densities are built up to high levels to be discharged in one large pulse at power levels several times above the continuous wave output of the same cavity. Q-switching of laser 11 is accomplished by removing the output mirror of its resonating cavity and replacing the mirror with a rotating mirror. The rotating mirror is rotated by a constant speed synchronous motor 24 at about 3000 rpm.

The novel feature of the invention appears to lie in the use of a laser to cut (continuous mode) or shatter (pulsed mode) ice in the path of a ship thereby enabling the ship to move through the ice.

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FIG. 1

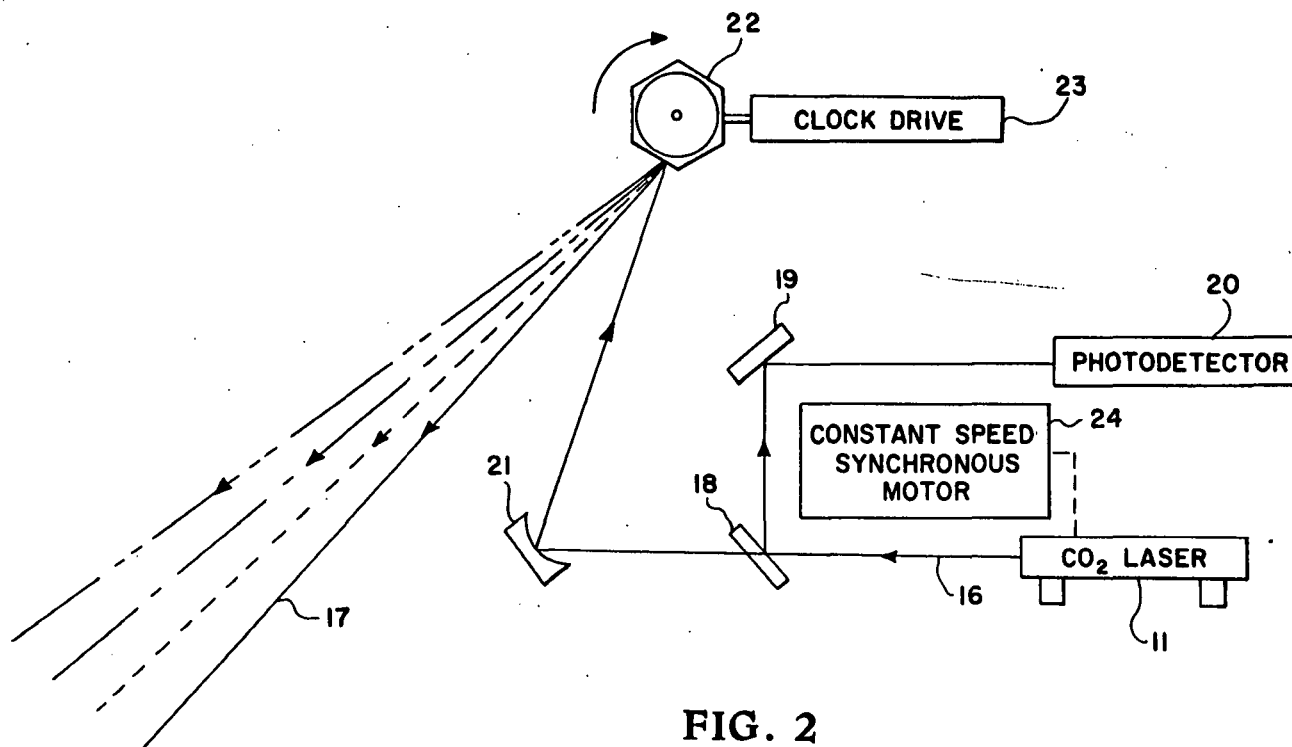


FIG. 2

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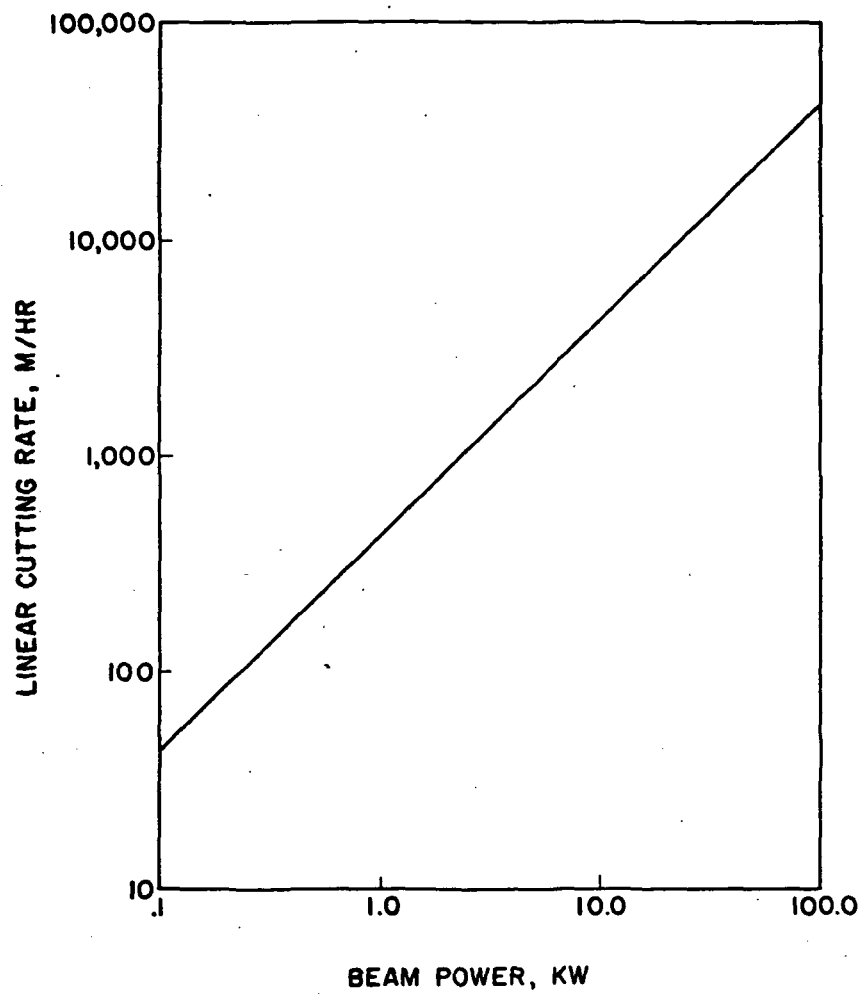


FIG. 3

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PRINT FIG. Figure 1

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provide a new technique for breaking the ice in the path of ships which eliminates or decreases the disadvantages found in prior art techniques.

SUMMARY OF THE INVENTION

5 In this invention a laser is placed on the bow of the ship and a mirror means is used to scan the beam of the laser across the layer of ice in front of the ship. There are two modes of operation used in this invention. In the first, the laser beam is a continuous beam which cuts the layer of ice; and in the
10 second, the laser beam is pulsed causing it to shatter the layer of ice. In both modes of operation the structure of the ice is weakened thereby enabling the ship to break the ice with much less ramming force than would be otherwise required. The laser used in this invention is a CO₂ or other gas laser with output
15 powers of 2500 watts or larger, operating in continuous wave or pulsed modes at 10.6 microns.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic drawing of an embodiment of the invention;

20 FIG. 2 is a block diagram of the apparatus used in the embodiment in FIG. 1; and

FIG. 3 is a graph of ice cutting rate in meters per hour versus beam power in kilowatts for gas lasers.

DETAILED DESCRIPTION OF THE INVENTION

25 Turning now to the embodiment of the invention selected for illustration in the drawings, the number 11 in FIG. 1 designates a laser that is attached to a ship 12. The ship is traveling through water that has a layer of ice 13 on top. As was discussed above, in the past the layer of ice 13 was broken
30 by explosives or by ramming with the ship. It is the purpose of this invention to use the laser 11 to break the ice or to aid

in the breaking of the ice. To accomplish this purpose, a scan mirror 14 is mounted on ship 12 with any suitable mounting means 15 such as a telescope pedestal. The details of scan mirror 14 are disclosed in FIG. 2. The beam 16 from laser 11 is directed into mirror 14 such that as mirror 14 rotates the reflected beam 17 scans the layer of ice 13 in the path of ship 12. There are two modes of operation for this invention: a continuous laser beam mode and a pulsed laser beam mode. In the continuous laser mode of operation, a groove is cut into the ice by the laser beam and in the pulsed mode of operation the ice is shattered by the laser beam. In either mode of operation, the structure of the ice layer 13 is weakened to the extent that ship 12 will move through the ice without any ramming or with substantially less ramming than would be required if no laser beam were used.

Referring to FIG. 2, there is shown a block diagram of the apparatus used with laser 11 and scan mirror 14 in FIG. 1. The beam 16 from CO₂ laser 11 is directed into a beam splitter 18. The part of beam 16 that is reflected is again reflected by a mirror 19 onto a photodetector 20 which indicates the intensity of the beam 16. The part of the beam 16 that passes through beam splitter 18 is reflected by a parabolic mirror 21 onto a rotating scan wheel mirror 22 which is driven in a clockwise direction by a clock drive 23. Scan mirror 22 has five surfaces, hence each time the mirror rotates through 72 degrees, the laser beam will be reflected by a different surface. Consequently, each time the mirror rotates through 72 degrees, the reflected beam 17 will scan from a point in front of the ship to the left through 72 degrees. The scan mirror can have any number of reflecting surfaces other than two as shown in FIG. 1 or five as shown in FIG. 2 without departing from this invention.

Q-switching of CO₂ laser 11 is required for operating the device in FIG. 2 in a high power, rapid-pulsed mode. In this mode, the inversion densities are built up to high levels to be discharged in one large pulse at power levels several times above the continuous wave output of the same cavity. Q-switching of CO₂ laser 11 is accomplished by removing the output mirror of its resonating cavity and replacing the mirror with a rotating mirror. The rotating mirror has a gold-coated optical surface and is rotated by a constant speed synchronous motor 24 at about 3000 rpm.

The CO₂ laser 11 can be a CO₂-N₂-He laser with an output power of 2500 watts or larger in the TEM₀₀ and TEM₀₁ modes combined with an output frequency of 10.6 μ m. The beam diameter is 1 cm with a beam divergence of less than 2 milliradians. Regulated d.c. excitation, flow-through water cooling is used with an input power requirement of 208 volts a.c., 50 to 60 Hz and at 2500 watts of output power.

All optical components have gold-coated optical surfaces with provisions for water cooling. The optics and laser cavity is mounted on an optical bench for accurate alinement. The rotating scan mirror 22 is mounted on a pedestal telescope mount for vertical and horizontal alinement to scan the target. The mirror 22 is driven by a synchronous motor electric clock drive 23 with speeds of 1/100 to 1 rpm allowing linear scan rates between 50-5000 m/hr.

In order to prove the feasibility of this invention, an experimentally cutting rate of 14.8 m/hr was obtained with a 35-watt CW CO₂ laser operated at 10.6 microns in single mode with the beam focused to 1/250 Cm diameter. Based on this experimentally obtained cutting rate, cutting rates were

calculated as a function of CO₂ laser beam output power for 0.1-100 KW as shown in FIG. 3. Linear cutting rates in excess of 1 km/hr can be obtained with beam powers of about 3 KW. Based on the results of the preliminary experimental studies the radiative energy conversion efficiencies are near the theoretical values for melting with only negligible vaporization and refreezing. Since the 10.6 μ m radiation is absorbed by the hydrogen bonds in the ice crystal lattice the energy will be used primarily to break these bonds selectively, resulting in melting with potentially less energy transfer into the translational modes than in conventional thermal excitation processes.

The advantages of this invention are numerous. It provides a technique for clearing ice from the path of a ship in which no explosives are used, thus avoiding a hazard to required personnel. Substantial structural reinforcement of the ship's hull is not necessary since very little, if any, ramming by the ship is required. Close contact with the ice is not needed. Not as large an expenditure of power is needed in the use of this invention as was required by previous techniques. When the technique of this invention is used, the ship's speed will be substantially greater than when previous techniques were used.

It is to be understood that the form of the invention herewith shown and described is to be taken as a preferred embodiment. Various changes may be made in the shape, size and arrangement of parts. For example, equivalent elements such as different lasers, different scanning mechanisms and different means for pulsing the laser beam may be substituted for those illustrated and described herein, parts may be reversed, and certain features of the invention may be utilized independently of the use of other features, all without departing from the spirit or scope of the invention as defined in the following claims.

What is claimed as new and desired to be secured by
Letters Patent of the United States is:

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